Effects Partial Solar Radiation on the Grapevine

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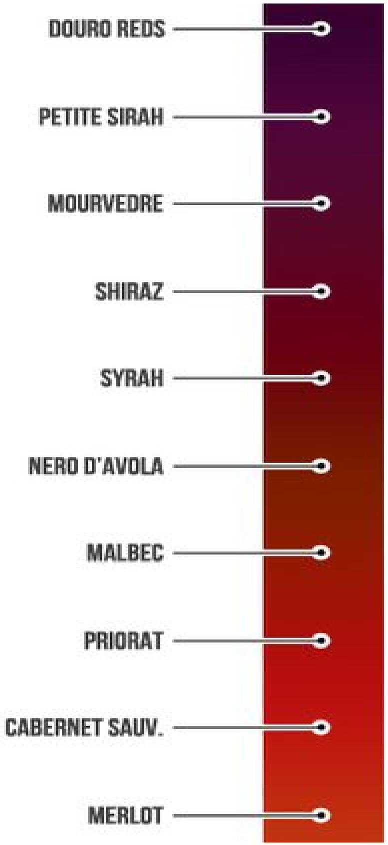
Flavonoids in grape berry

- Properties
  - Color
  - Co-pigmentation
  - Astringency (tactile)
  - Bitterness (taste)
- Health-promoting effects
- Important antioxidant capacity



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Berry Anatomy

Flesh (pulp)
- juice
- hydroxycinnamates

Seed
- tannins (bitter)
- flavan-3-ols
- hydroxybenzoic acids

Skin
- color pigments
- tannins (astringent)
- flavan-3-ols
- flavonols

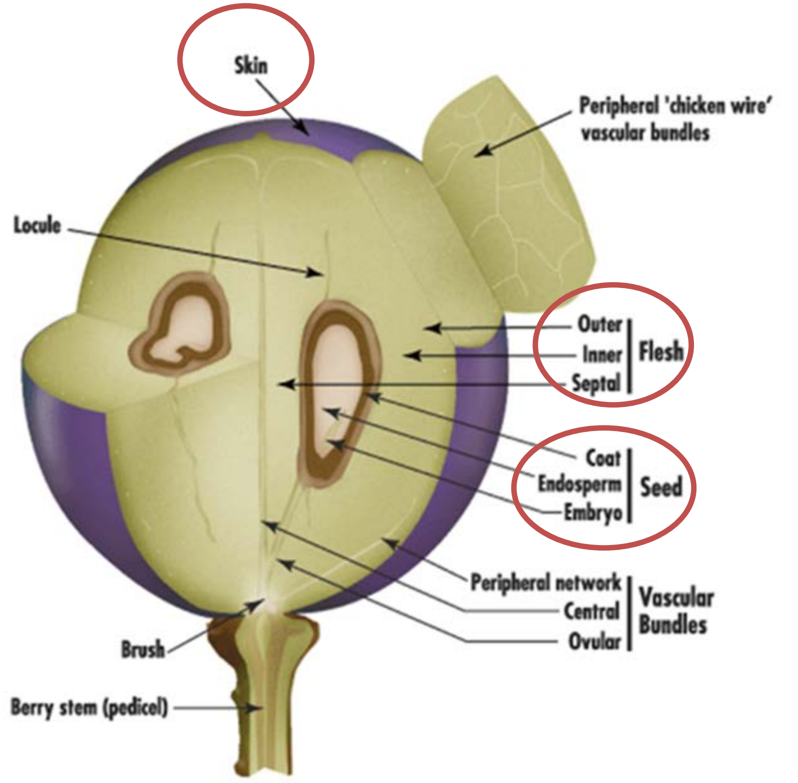
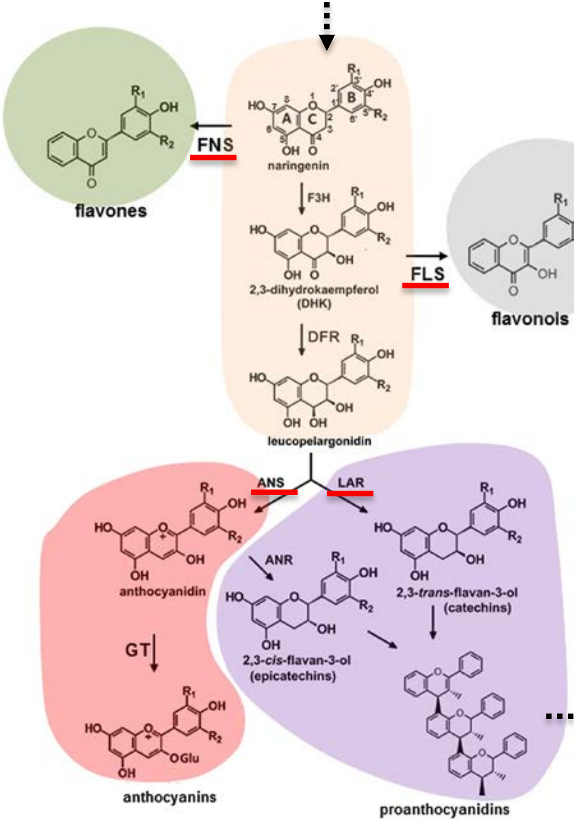


Figure 1: Structure of a ripe grape berry partially sectioned on the long and central axis to show internal parts. Illustration by Jordan Koutroumanidis, Winetitles.

Illustration by Jordan Koutroumanidis, Winetitles

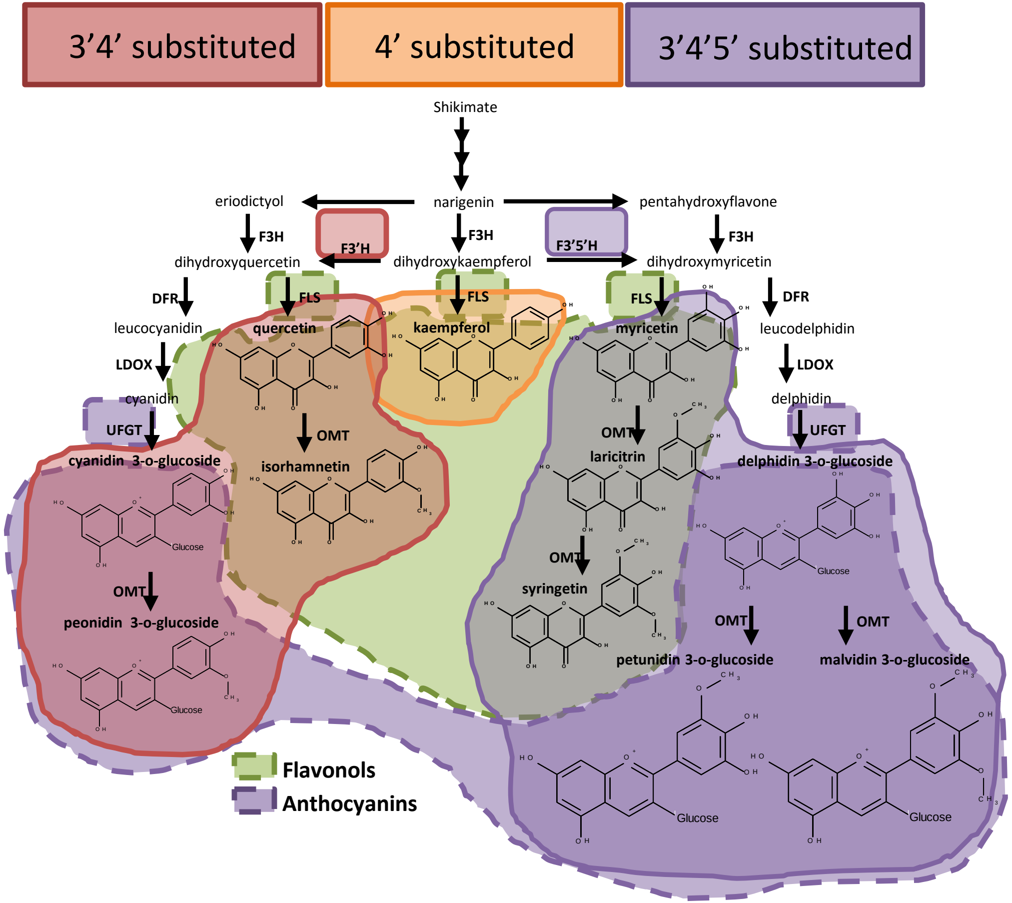
Flavonoid biosynthesis

Phenylalanine (phenyl propanoid pathway)



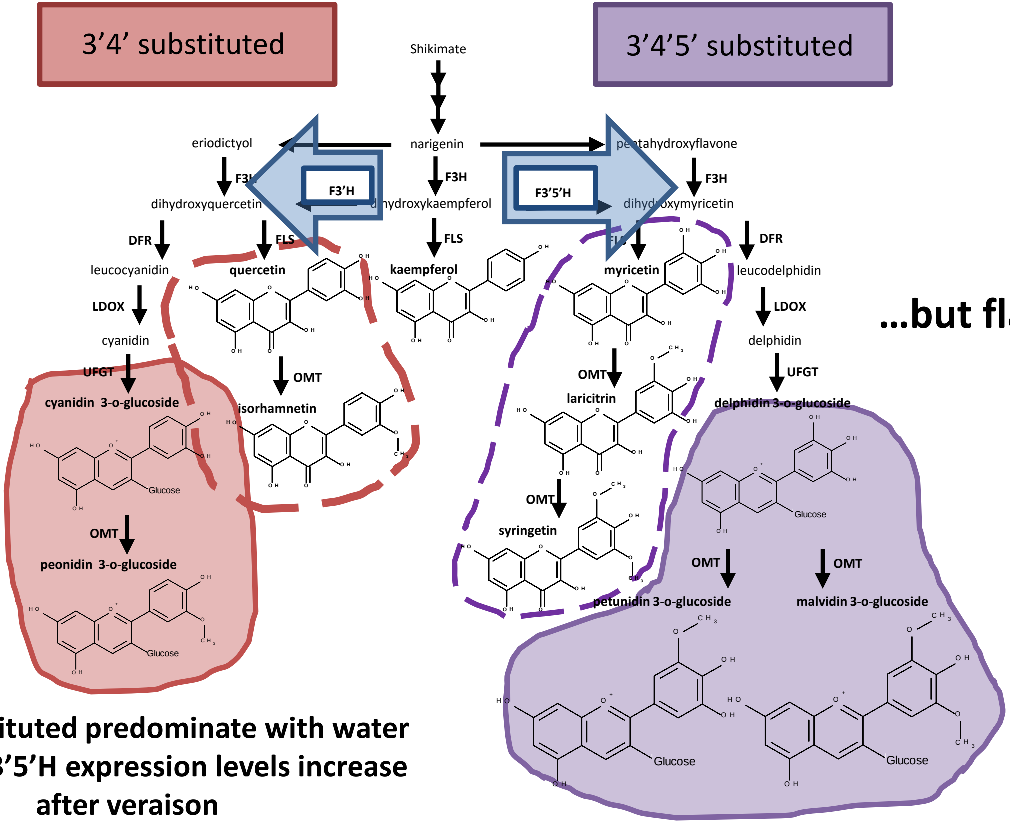
Tannins

Constitution of flavonol and anthocyanin profiles



Abbreviations: F3'H: flavonoid 3'-hydroxylase; F3'5'H: flavonoid 3'5'-hydroxylase; FLS: flavonol synthase; DFR: dihydroflavonol reductase; LDOX: leucocyanidin dioxygenase; UFGT: UDP-glucose flavonoid 3-*O*-glucosyltransferase; OMT: *O*-methyltransferase

Effect of water deficit on profiles



…but flavonols?

3'4'5' substituted predominate with water deficit as F3'5'H expression levels increase after veraison

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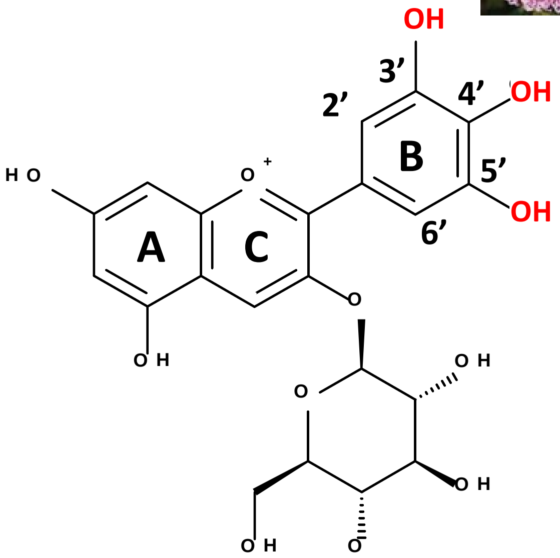
Castellarin et al., 2007 (Planta; BMC Plant Biology; Plant Cell and Environment)

3’4’5’ substituted

Anthocyanins

Flavonol homologues



Cyanidins F3’H Quercetins

Pelargonidins
Uncommon in *Vitis vinifera* grapes

Kaempferols

Delphidins F3’5’H Myricetins

Flavonols impact on wine mouthfeel

Red wine *p<0.1; ** p<0.01

White wine *p<0.1; ** p<0.01

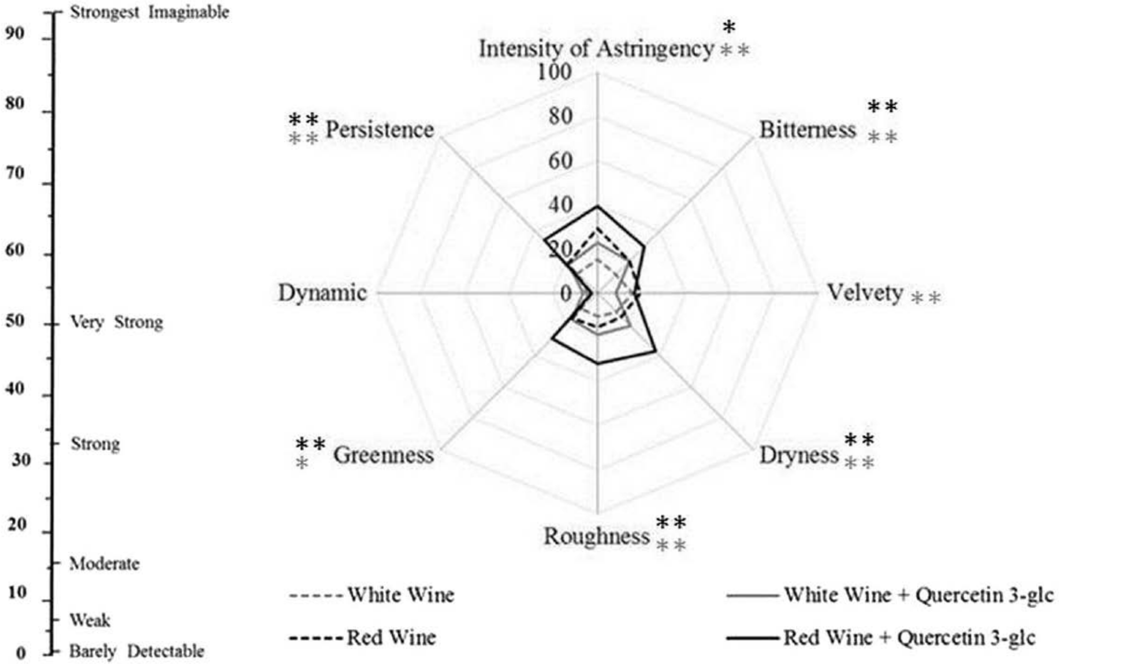


Fig. 1. Sensory analysis of white and red wines before and after the addition of quercetin 3-O-glucoside (2 g/L).

Ferrer-Gallego *et al.*, 2016

Proanthocyanidins

Important due to their astringent properties

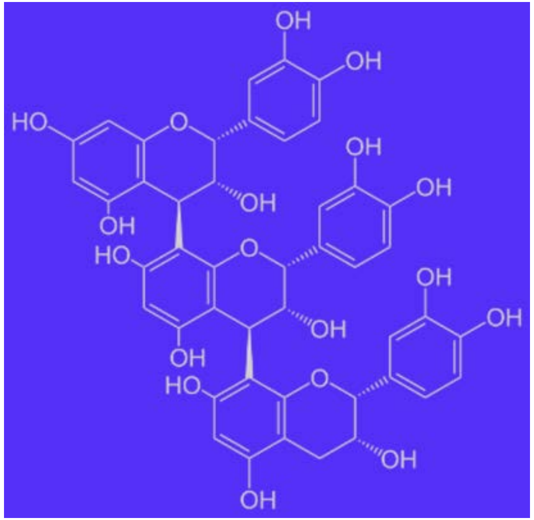
Role in long term color stability

Grape based proanthocyanidins

- (+)-catechin (C)
- (-)-epicatechin (EC)
- (-)-epicatechin-3-*O*-gallate (ECG)
- (-)-epigallocatechin (EGC)

Skin vs. seed proanthocyanidins

- Skins contain EGC
- Greater degree of polymerization
- Lower proportion of galloylated subunits



How can we relate this information to tactile and taste sensation?

Increase Tannin Molecular Size→ increase astringency/ chalky

Sun et al, *J. Agric. Food Chem*. 2013, 61: 939-946

Vidal et al, *J Sci Food Agric.* 2003, 83: 564–573

Increase %ECG→ increase drying and chalkiness

Vidal et al, *J Sci Food Agric.* 2003, 83: 564–573

Increase %EGC→ lower coarseness

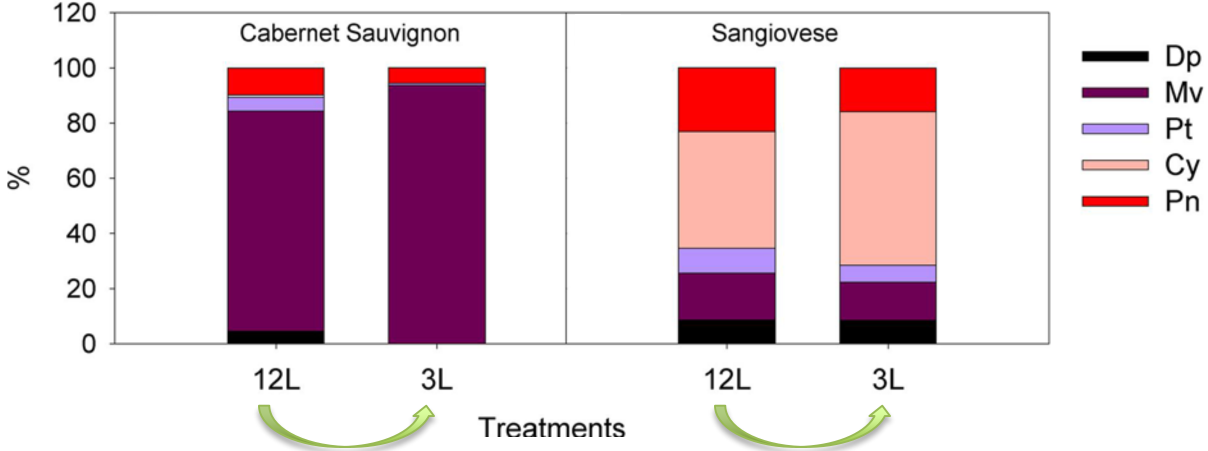
Vidal et al, *J Sci Food Agric.* 2003, 83: 564–573

Increase Color Incorporation→ less astringent

Vidal et al, *Analytica Chimica Acta.* 2004, 513: 57-65

Varietal differences and effects of management practices

Anthocyanin profile composition



Effect of controlling vegetation

Bobeica *et al.*, 2015

Effect of water deficit on wine hue

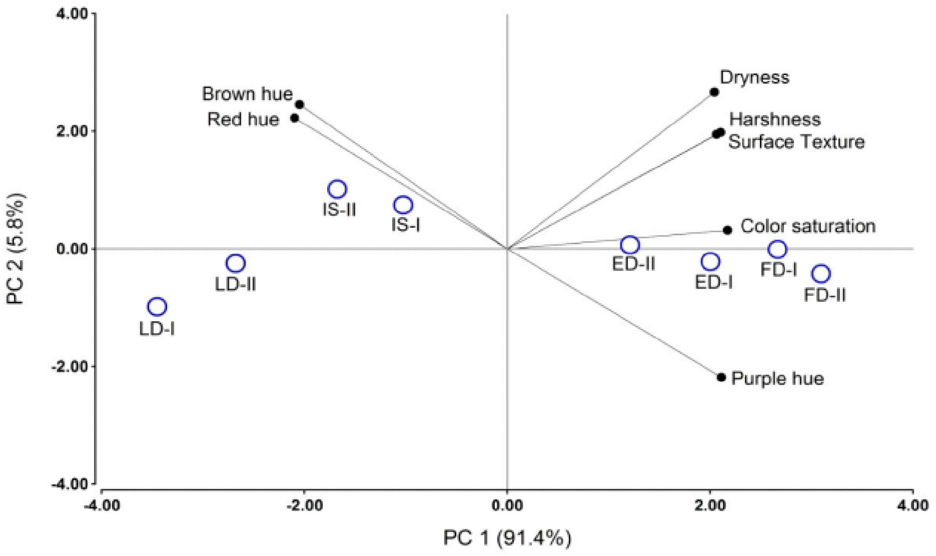


Figure 6. Principal Component Analysis of sensory data of the 2008 wines obtained from field-grown, own-rooted Cabernet Sauvignon grapevines in the Columbia Valley, WA (USA). All the two wine replicates were included in the analysis and are indicated as "I" and "II". IS: industry standard; ED: early deficit (fruit set to *véraison*); LD: late deficit (*véraison* to harvest); FD: full season deficit (fruit set to harvest).

Cassasa et al., 2015

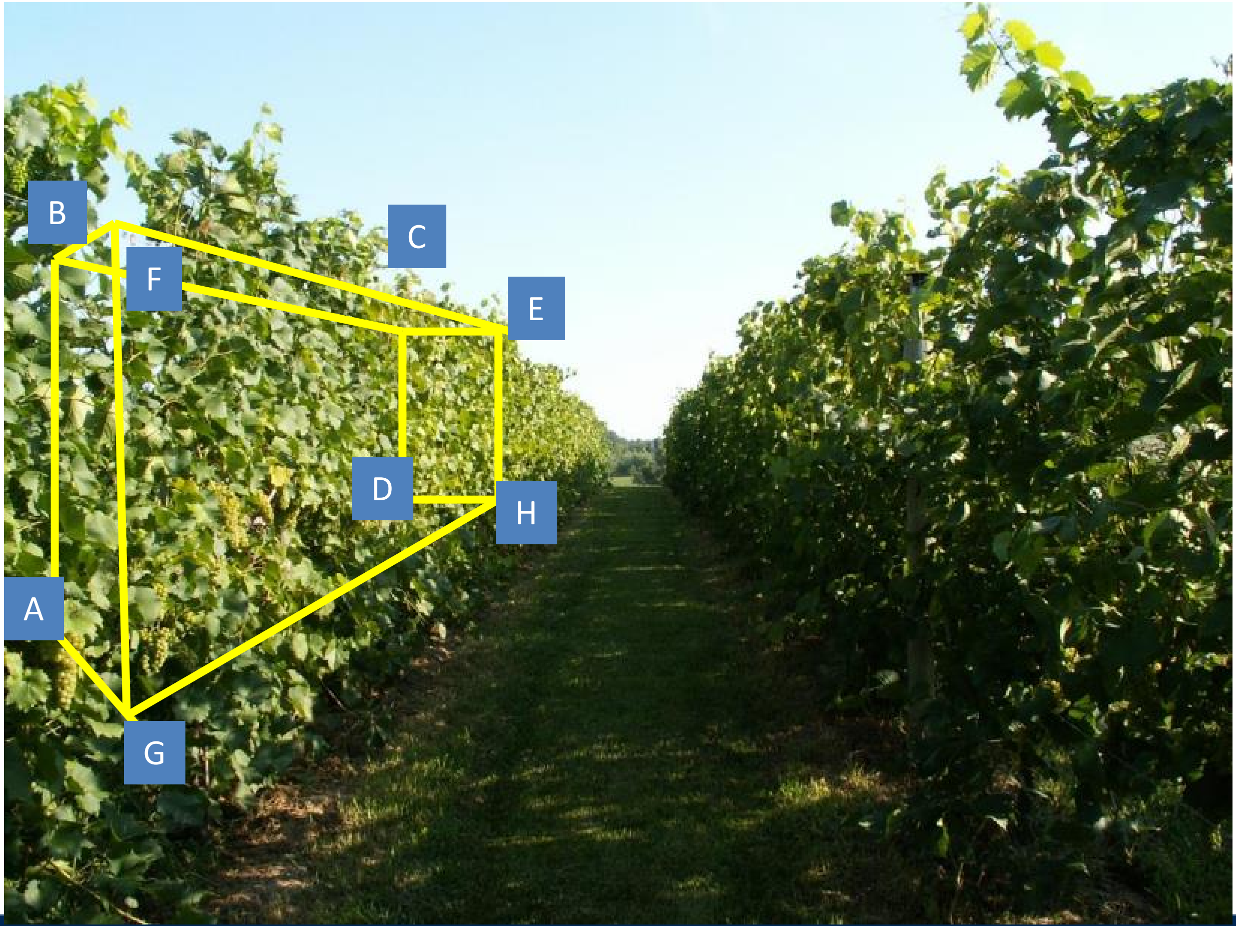
Changing environment in California

- Less cloud coverage, increasing temperatures
- Yield loss:
  - Direct: Berry water content, shriveling
  - Indirect: Acidity, astringency, color hue
- Shifts in:
  - Phenology
  - Compositional shifts in flavonoid profile

Optimum light environment in the fruit zone during ripening

Maximize diffuse or indirect sunlight within the canopy interior

Minimize exposure of clusters to direct sunlight – particularly in warm climates


B
C
F
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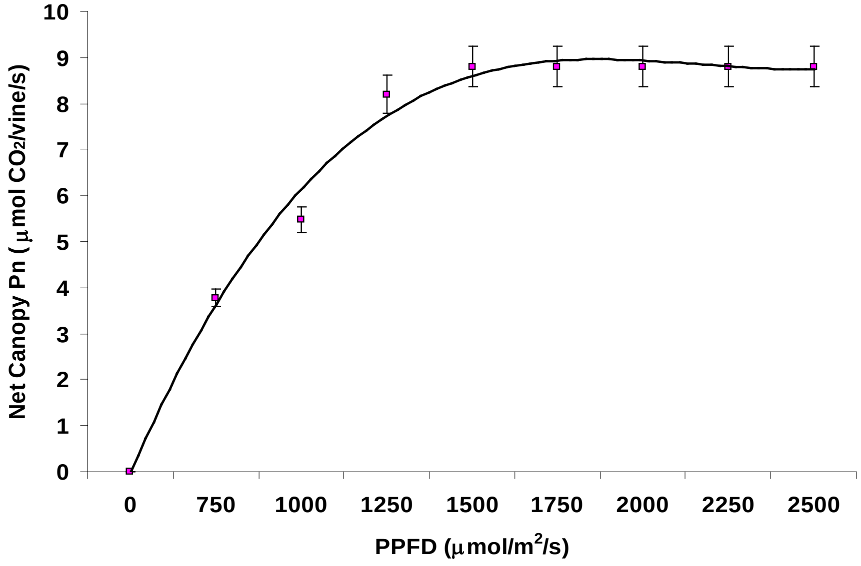
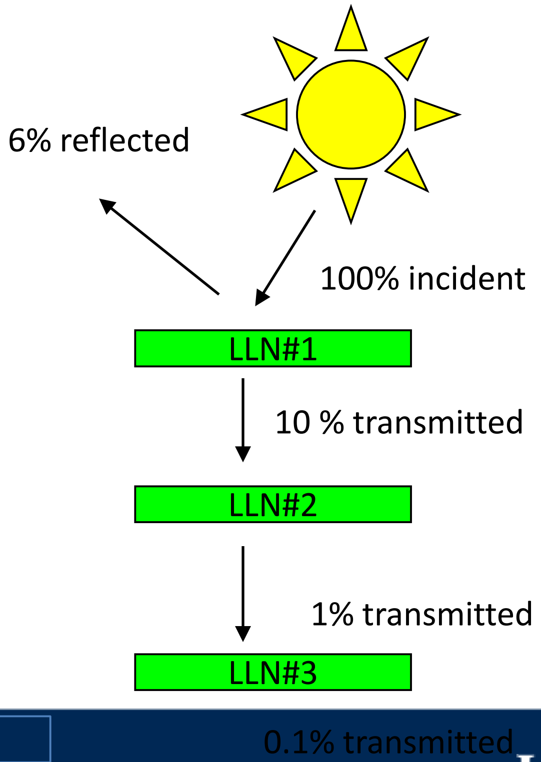
Radiation Effects on Whole Canopy





Kurtural et al. 2003; Dami et al. 2005; Kurtural et al. 2005; 2006

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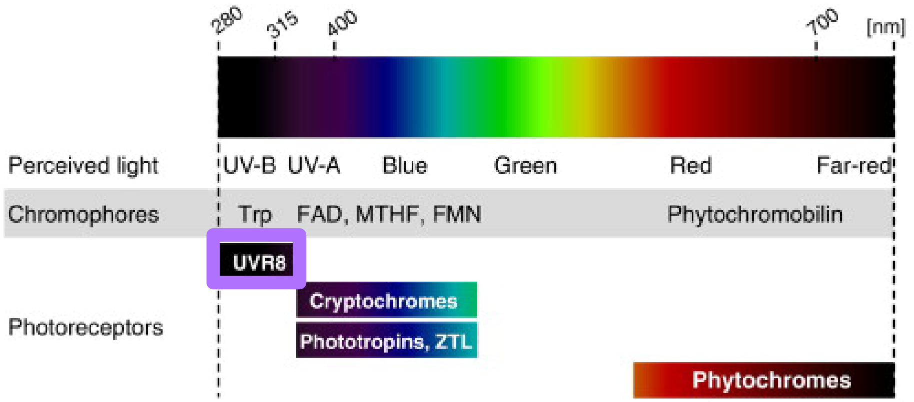
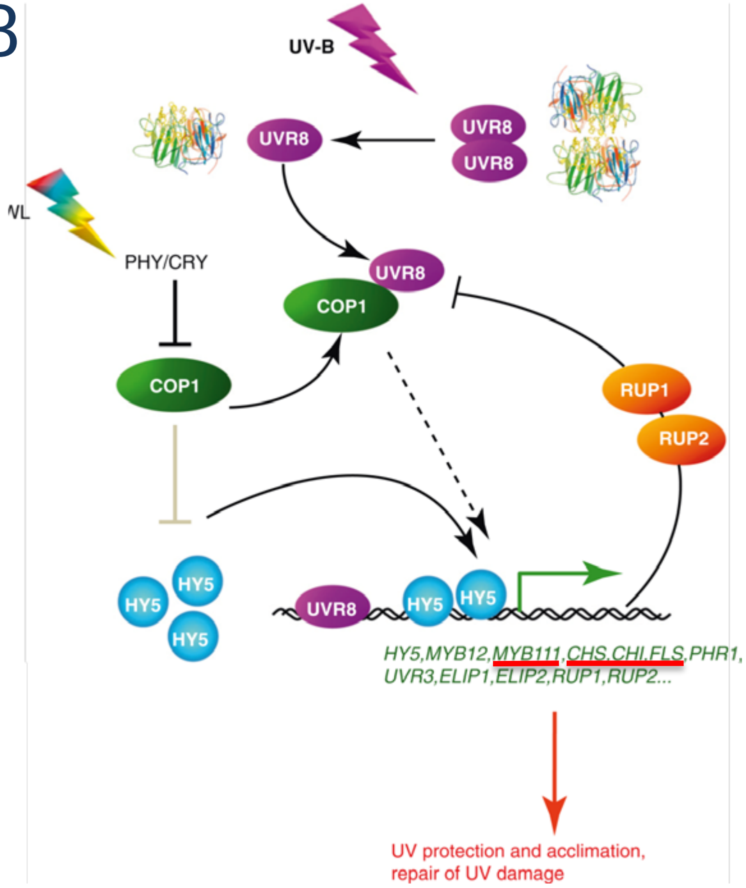
Plant UV-B photoreception : UVR8





Heijde and Ulm 2013 Trends Plant Sci.

Experiment at Oakville Experiment Station

Vineyard description

- Four year old producing vineyard CS clone 7/C3309.
- Spacing: 6’ x 8’, NW-SE orientation
- Bi-lateral cordon, relaxed vertical shoot-positioned training system

Experimental design

- Five colored shade nets (and untreated control)
- Two applied water amounts
- Arranged factorially in a split-plot design with four blocks

Colored shade nets

- Five polyethylene cloths with ~ 80% transmissivity of visible light
    - Blue
    - Pearl
    - Aluminet
    - Red
    - Black
- Untreated control

Applied water amounts

- Well watered (SDI): 65% of estimated ETc and applied to maintain a mid-day leaf water potential ψl of -1.2 MPa, from fruit set to harvest.
- Deficit watered (RDI): applied at the same ψl with SDI soon after bud break but was decreased to 25% ETc from fruit set to veraison with a ψl of -1.4 MPa and then reinstated to SDI from veraison until harvest.

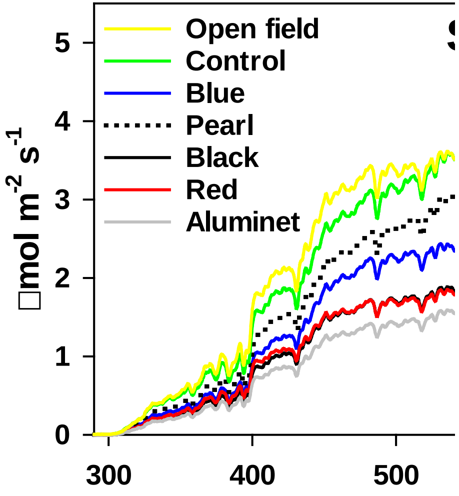
RESULTS

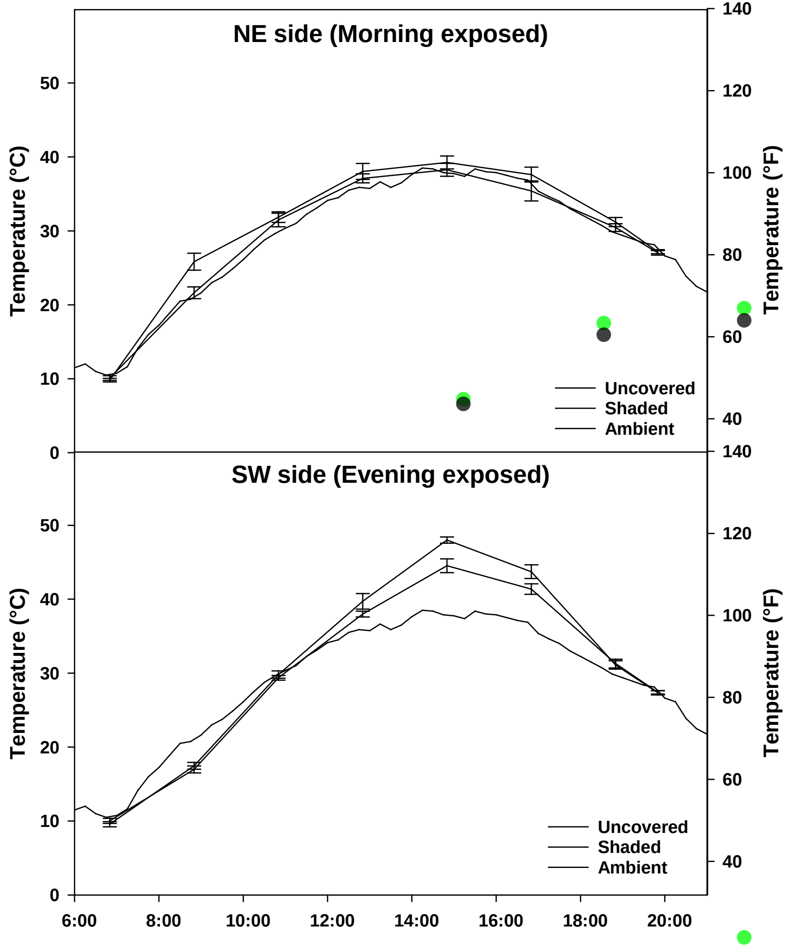
What do the these nets actually do?

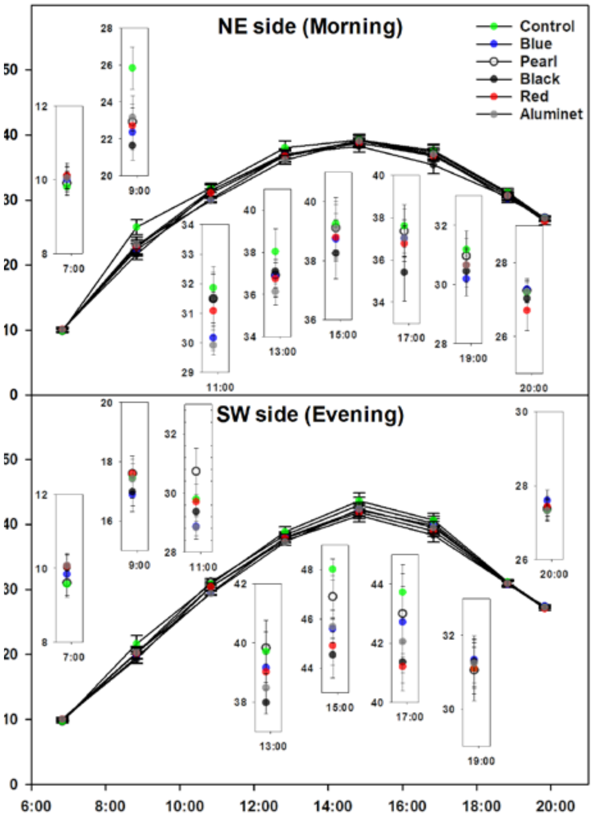
Transmittance of wavelengths by net color

WL range	% Tr Black	% Tr White	% Tr Silver	% Tr Red	% Tr Blue
UV-B	76.31	71.72	60.63	58.41	49.27
UV-A	79.64	72.75	63.74	67.00	44.52
Violet	79.52	75.81	67.51	67.18	51.36
Blue	88.40	91.54	88.02	79.75	74.55
Green	99.99	99.96	99.98	99.96	99.99
Yellow	99.99	99.96	99.98	99.96	98.65
Red	97.69	99.93	98.65	99.93	75.86
Far red	83.18	86.48	78.14	91.79	59.94
Fr/R	85.15	86.54	79.21	91.85	79.02

Physical conc







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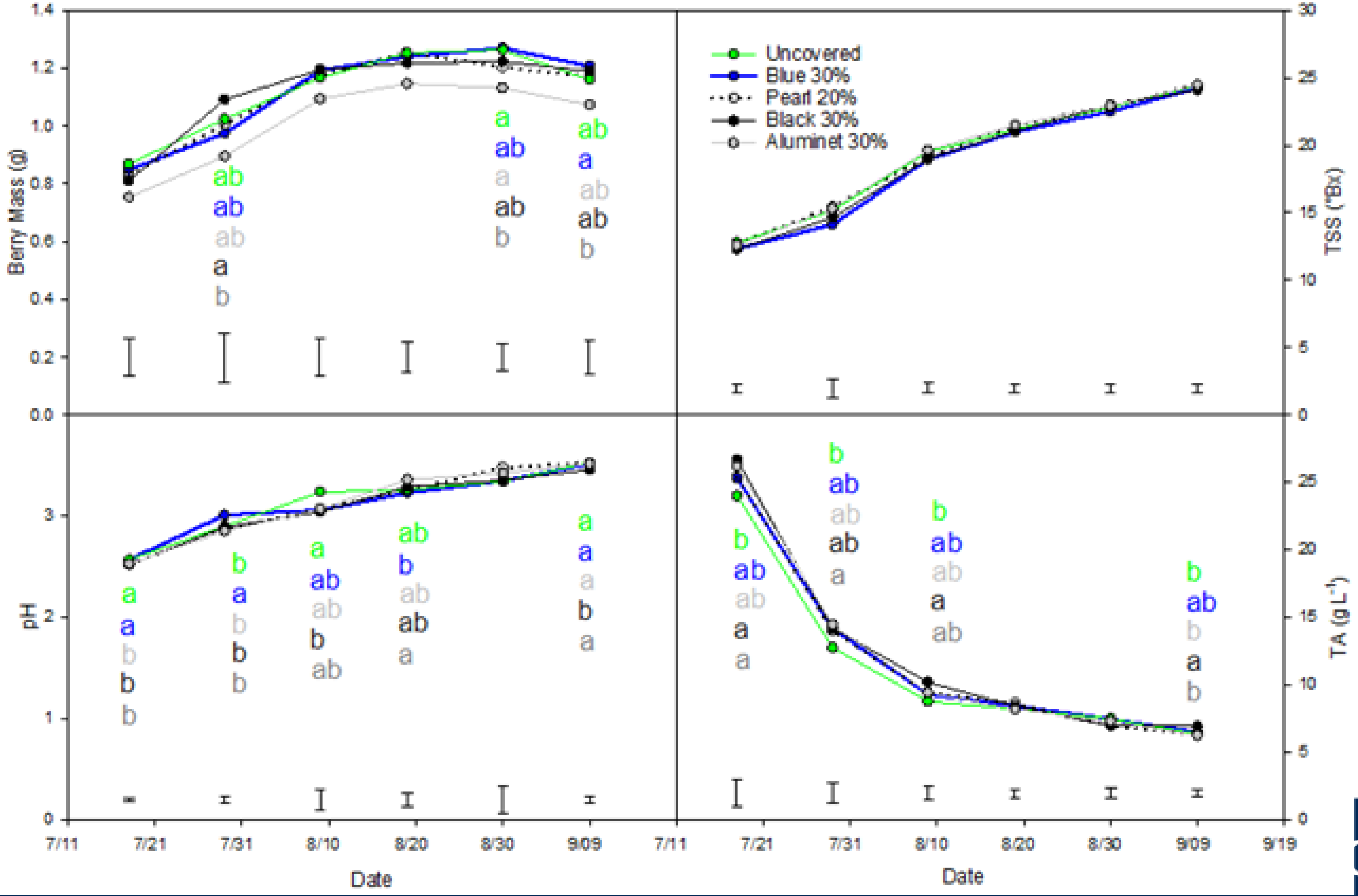
Components of yield

Water applied	Net Cover	Berry Mass (g $Berry^{-1}$)	Cluster mass (g)	Yield (kg/vine)
SDI	Control	1.15	214	8.0
	Blue	1.29	209	7.9
	Pearl	1.20	190	7.7
	Black	1.32	196	8.1
	Red	1.16	203	7.2
	Aluminet	1.10	214	6.4*
RDI	Control	1.13	196	8.1
	Blue	1.20	202	7.6
	Pearl	1.17	196	7.6
	Black	1.20	205	7.5
	Red	1.24	202	7.0
	Aluminet	1.19	213	8.5
$P_{(net)}$		0.043	0.2658	0.4519
$P_{(water)}$		0.289	0.8403	0.2233
$P_{(cnets\ x\ water)}$		0.347	0.6905	0.0059

Berry



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Water applied	Net Cover	Berry Mass (g $Berry^{-1}$)	Total Anthocyanins (mg $Berry^{-1}$)	Anth. Profile Hydroxylation 3'4'5'/3'4'	TSS (Brix°)	pH	Titratable Acidity (g L^{-1})
SDI	Control	1.15	1.47	11.12	24.45	3.52	6.38
	Blue	1.29	1.65	12.58	24.38	3.51	6.50
	Pearl	1.20	1.51	11.98	24.70	3.52	6.38
	Black	1.32	1.67	12.11	24.15	3.44	6.87
	Red	1.16	1.35	11.88	24.23	3.48	6.50
	Aluminet	1.10	1.57	10.80	24.40	3.52	6.28
RDI	Control	1.13	1.74	12.44	24.15	3.47	6.65
	Blue	1.20	1.48	13.85	23.90	3.47	6.65
	Pearl	1.17	1.53	12.82	23.88	3.47	6.83
	Black	1.20	1.36	12.94	23.85	3.48	6.40
	Red	1.24	1.72	12.64	24.15	3.48	6.53
	Aluminet	1.19	1.47	13.47	24.10	3.45	6.68
$P_{(cloth)}$		0.043	0.192	0.454	0.337	0.087	0.943
$P_{(water)}$		0.289	0.215	0.008	<0.001	0.004	0.113
$P_{(cloth\ x\ water)}$		0.347	0.083	0.817	0.293	0.774	0.938

In vines without nets (Control), well exposed berries did not make it to the end of the experiment!

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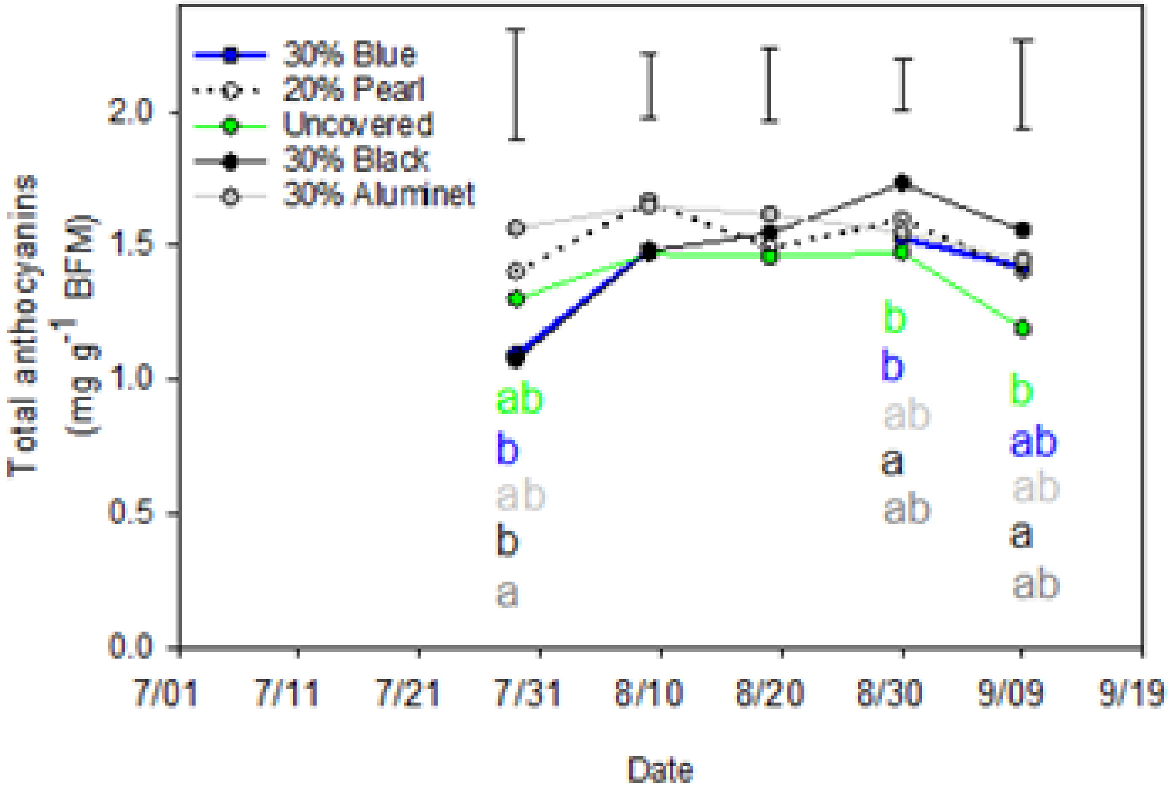
Kinetic



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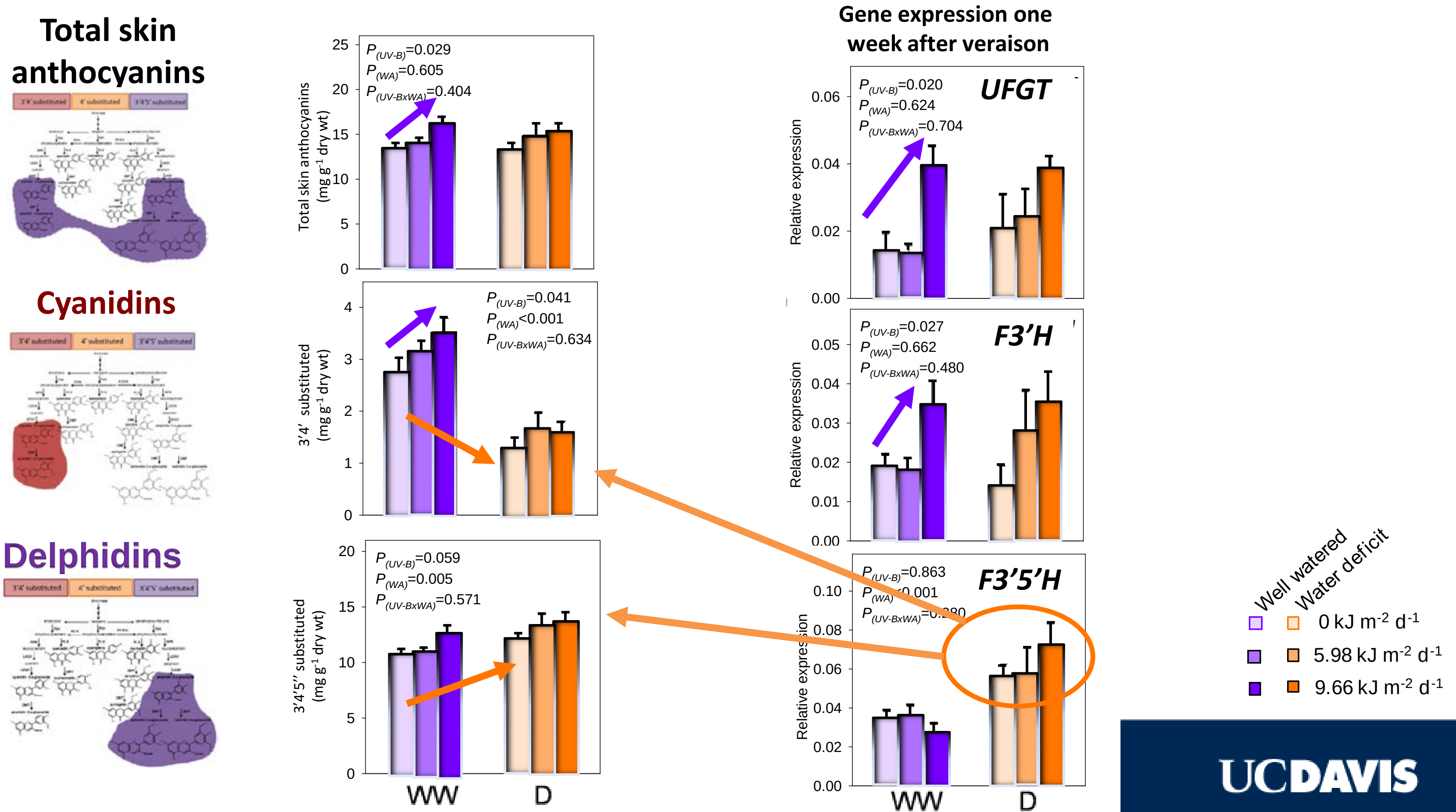
UV-B and water deficit affected differently the anthocyanin groups



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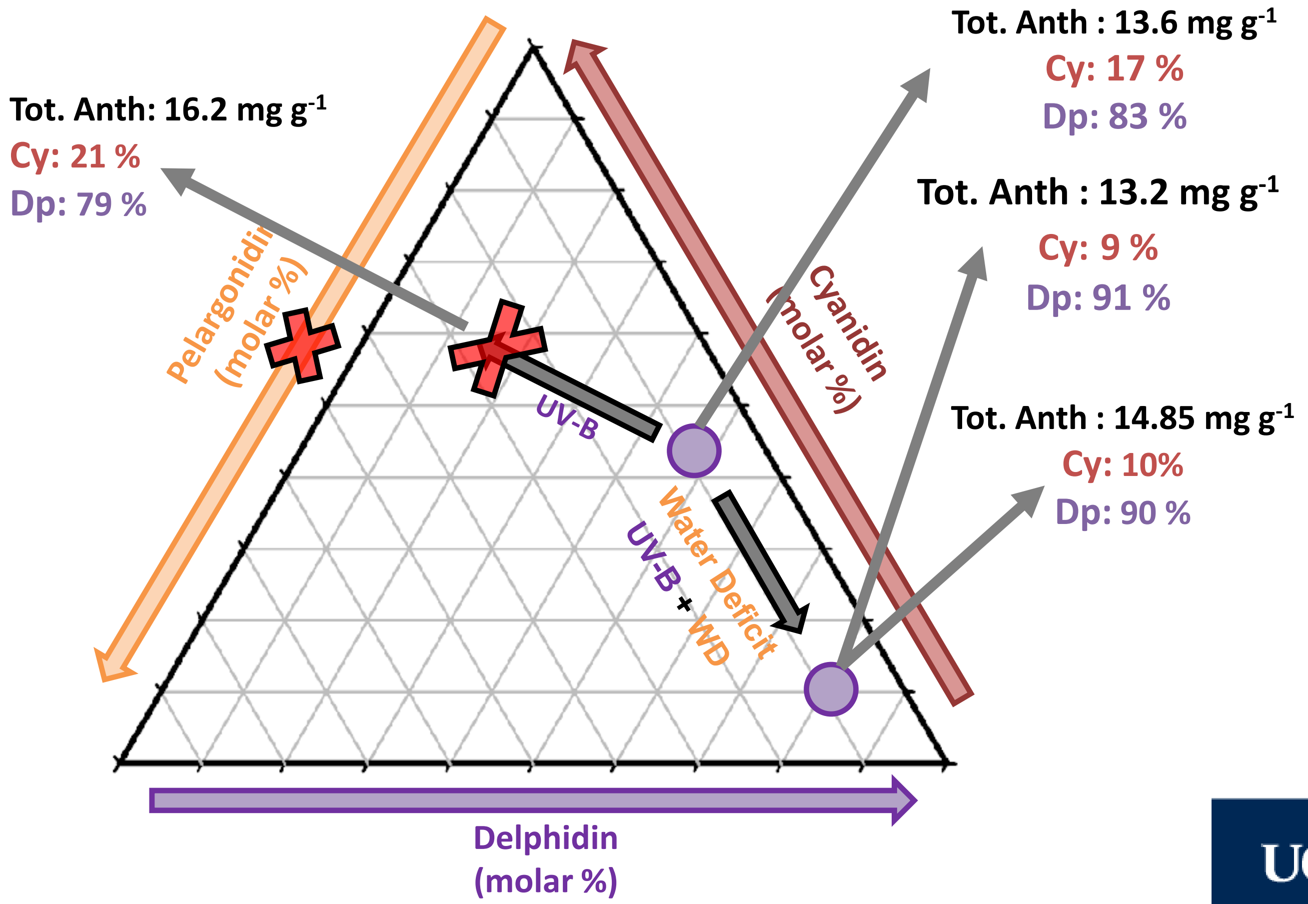
Anthocyanin profile hydroxylation under higher light and water deficit



Water applied	Net cover	**Skin mDP**	**Seed mDP**
SDI	Control	52	6.9
	Blue	46	7.1
	Pearl	49	7.1
	Black	50	6.7**
	Red	47	6.7**
	Aluminet	51	7.4
RDI	Control	47	8.0
	Blue	45	6.5**
	Pearl	47	7.4
	Black	48	7.7
	Red	50	7.7
	Aluminet	51	7.7
$P_{(nets)}$		0.5392	0.1390
$P_{(water)}$		0.8590	0.0029
$P_{(nets\ x\ water)}$		0.6126	0.0454

In vines without nets (Control), well exposed berries did not make it to the end of the experiment!

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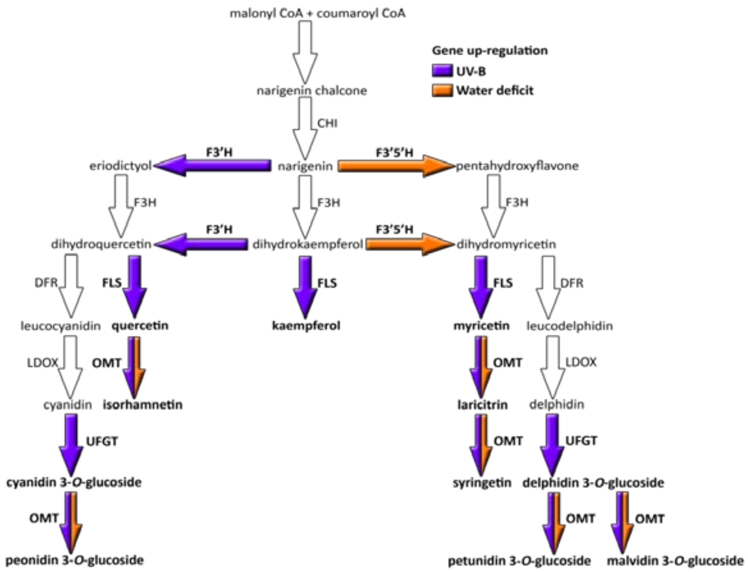
How can we explain flavonol-anthocyanin profile behavior with transcript levels?



- Total flavonols
- Total anthocyanins
- Methylated Flavonols
- Methylated Anthocyanins
- Quercetins
- Cyanidins
- Methylated Flavonols
- Methylated Anthocyanins
- Delphidins
- Myricetins

Discussion

- Whereas moderate solar radiation exposure can equilibrate berry acidity and promote anthocyanin biosynthesis;
    - extreme temperatures can lead to organic acids and anthocyanin degradation (Mori et al., 2007; Sweetman et al., 2014).
- In the present study, the 3.5°C reduction in temperature in the moment of highest berry temperature (i.e. 15:00 Hrs in the SW side) was associated with ameliorated berry composition.
    - Greater anthocyanin content in berry
- Uncovered grapevines often displayed a greater level of proportion of berries with sunburn.

So far based on 2016 results…

- Primary metabolism:
  - Yield reduction: Aluminet
  - RDI irrigation treatment: Greater Brix accumulation
- Secondary metabolism:
  - Hydroxylation of anthocyanins: Greater with Blue +RDI
  - No measurable effect on skin mDP (tactile)
  - Seed mDP > Control +RDI => Greater bitternes (taste)
  - Seed mDP < Black, Red +SDI or Blue+RDI => Less bitterness (taste)

Thank you for listening!